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A Survey on mobility Models & Its Applications

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Abstract— In this paper, we survey the current scenario available in the field of wireless ad-hoc network. The performance of mobile ad-hoc network (MANET) application depends on several parameters like no. of nodes, node density, communication traffic pattern, communicating range of a node, routing protocol, battery power of a node, mobility etc. Out of these mobility plays an important role. There are several types of Mobility model like Random Way Point (RWP), Mobility models with temporal dependency, mobility model with spatial dependency. We provide a discussion on the existing mobility models, their definitions and their limitations along with the simulation done so far in the field of it.
Keywords- MANET, Mobility Models- RWP, RPGM, Gauss Markov Mobility Model etc.

I. INTRODUCTION

Wireless network has become very popular in the computing industry. Wireless network are adapted to enable mobility. There are two variations of mobile network. The first is infrastructure network i.e. a network with fixed and wired gateways. The bridges of the network are known as base stations. A mobile unit within the network connects and communicates with the nearest base station, within the communication radius. Application of this network includes office WLAN. The second type of network is infrastructure less mobile network commonly known as AD-HOC network. A Mobile Ad-Hoc Network (MANET) is a self-configuring network of mobile nodes connected by wireless links, to form an arbitrary topology. The nodes are free to move randomly. Thus the network's topology may be unpredictable and may change rapidly. Ad hoc wireless network can be deployed quickly at anytime and anywhere as they do not required fixed infrastructure setup. Hence, these features make ad-hoc network suitable for the many applications like mobile classroom, battlefield communication, disasters relief, Museum touring and emergency situations like natural disasters, military conflicts, and emergency medical situations etc. Since most of the MANETs are not deployed because of their deployment cost is very high so lot of research work is simulation based and in most of the simulation work RWP Mobility model is used because of the simplicity.

1.1 Mobility is an important parameter

In all the MANET application nodes can move from one location to another so there is mobility and if we study about all these mobility patterns then we can see different mobility pattern and scenarios have been generated in these MANET application hence mobility plays an important role in determining the performance of MANET application [1]. A mobility model, used in a simulation must be capable to show the same movement pattern of the nodes, as given in a trace file for a real life application.

1.2 Mobility Models and Its Need

Mobility model describe the movement pattern of mobile nodes like how their location, velocity, direction and acceleration will change with respect to time. Since movement patterns may play a significant role in determining protocol performance, it is desirable for mobility models to generate the movement pattern of targeted real life applications in a reasonable way. Otherwise, the observations made and the conclusions drawn from the simulation studies may be misleading. For example, the nodes in Random Waypoint model behave quite differently as compared to nodes moving in groups [3]. Therefore, there is a need for developing a deeper understanding of mobility models and their impact on protocol performance.

In this paper a discussion has been done on different types of mobility models like Random Way Point mobility model, Mobility Model with Temporal dependency, Mobility Model with spatial dependency. Further, a survey on existing work done in the same field has been proposed.

II. MOBILITY MODELS

Mobility models are used to describe the starting location of the nodes, their velocity direction, velocity range and pause time of the nodes. Based on mobility characteristics mobility models can be classified as, random way point mobility model, mobility model with spatial dependency, mobility model with temporal dependency, mobility with geographic restrictions.

2.1 Random Way Point Model (RWP):

Because of the simplicity of RWP model, it is one of the most frequently used mobility model in MANET simulation. Also, Network Simulator (NS-2) provide the setdest tool to generate the node trace of the of the Random Waypoint model.

In this mobility model mobile nodes move randomly and freely without any restrictions. First each mobile node selects one location from the simulation area as the destination. The node travels towards the destination with constant velocity chosen uniformly and randomly from $[V_{min}, V_{max}]$. Upon reaching the destination, the node stops for a duration, defined by the 'pause time' parameter T_{pause}. This pause time may be a constant value or it may follow a kind distribution. After the pause time, node again chooses another point as a destination and chooses a velocity from the given velocity range and move towards it. The process is repeated again and again until simulation ends. In RWP model, velocity range $[V_{min}, V_{max}]$ and T_{pause} are the two key parameters that determine the mobility behavior of the nodes. By varying these two parameters RWP model can generate various scenarios.

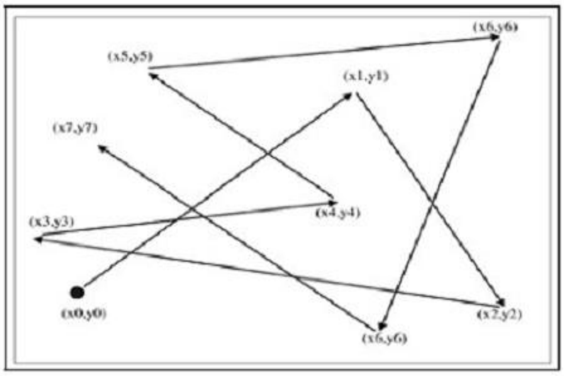

Fig-1: Movement of nodes in Random Way Point Model

2.1.1 Limitation of random way point mobility model

Though because of the simplicity of implementation and analysis, RWP is widely used mobility model in most of the MANET simulation, however it is inefficient to capture mobility characteristics of real life scenarios including temporal dependency, spatial dependency and geographical restrictions.

a. Temporal dependency: In Random Waypoint, the velocity of mobile node is a memory less random process, i.e., the velocity at current time is independent of the previous velocity. This may cause to sharp turn, sudden stop and sudden accelerate. However, in many real life scenarios the speed of vehicles and pedestrians will accelerate incrementally and change their direction smoothly.

b. **Spatial Dependency of Velocity:** In Random Way point, the mobile node can move independently of other nodes. However, in some scenarios including battlefield communication, rescue operations and museum touring, the movement pattern of a mobile node may be influenced by certain specific 'leader' node in its neighbourhood.

c. **Geographic Restrictions of Movement:** In Random Way point, the mobile nodes can move freely within simulation field without any restrictions. However, in many realistic cases, especially for the applications used in urban areas, the movement of a mobile node may be bounded by obstacles, buildings, streets or freeways. Random Waypoint model fails to represent some mobility characteristics likely to exist in MANET.
Random Way Point model was insufficient to capture the all these mobility characteristics hence other mobility models have been proposed.

2.2 Mobility Model with Spatial Dependency:
In the RWP model, a mobile node moves independently of other nodes, i.e., the location, speed and movement direction of mobile node are not affected by other nodes in the neighborhood. While in real life this is not always possible, for example, on a freeway to avoid collision, the speed of a vehicle cannot exceed the speed of the vehicle ahead of it. Also in some other MANET applications like disaster relief and battlefield communications team collaboration is required and team members try to follow their team leaders. That means, mobility of a node could be influenced by other neighboring nodes. Such behavior of mobile nodes can be modeled by a group mobility model.

2.2.1 Reference Point Group mobility Model (RPGM):
In RPGM mobility model, nodes move in to the groups. Each group has a logical centre called Group Leader, which determines group's motion behavior. Initially, each member of the group is uniformly distributed in the neighborhood of the group leader. Subsequently, at each instant, every node has a speed and a direction that is derived by randomly deviating from the Group Leader.

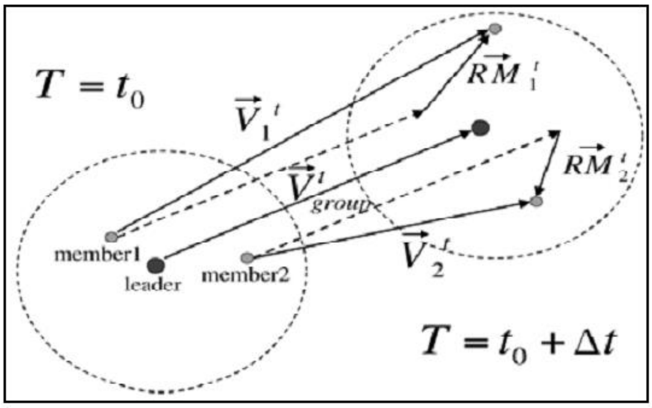

Fig-2: Node movement in RPGM mobility model at time t_0 and t+1 [6]

As shown in fig-2 the movement of the group member 'i' at time instant 't' is given as:

$$V_i^t = V_{group}^t + RM_i^t$$

Where the motion vector RM_i^t is a random vector deviated by group member 'i' from its own reference point. The vector RM_i^t is an independent identically distributed (i.i.d) random process whose length is uniformly distributed in the interval [0, r_{max}] where r_{max} is the maximum allowed distance deviation and direction is uniformly distributed in the interval [0,2*π] and $\mathrm{V}_{\mathrm{group}}^{\mathrm{t}}$is the velocity of group leader.

In RPGM model, the vector $\mathrm{RM}_{\mathrm{i}}^{\mathrm{t}}$ determines how much the motion of group members deviate from their leader. So, it's not possible to generate the various mobility scenarios with different levels of spatial dependency, by simple adjustment of model parameters. So, a modified version of RPGM model is proposed. The movement can be characterized as follows:

$$\left|\mathrm{V}_{\mathrm{member}}^{\mathrm{t}}\right| = \left|\mathrm{V}_{\mathrm{leader}}^{\mathrm{t}}\right| + \mathrm{random}() * \mathrm{SDR} * \mathrm{max\_speed}$$
$$\left|\theta_{\mathrm{member}}^{\mathrm{t}}\right| = \left|\theta_{\mathrm{leader}}^{\mathrm{t}}\right| + \mathrm{random}() * \mathrm{ADR} * \mathrm{max\_angle}$$

Where $0 < SDR, ADR < 1$. SDR is the Speed Deviation Ratio and ADR is the Angle Deviation Ratio.

$\mathrm{V}_{\mathrm{i}}^{\mathrm{t}}$ = Velocity vector of node i at time t.

$\theta_{\mathrm{i}}^{\mathrm{t}}$ = Angle made by $\mathrm{V}_{\mathrm{i}}^{\mathrm{t}}$ at time t with the X-axis.

2.3 Mobility Model with Temporal Dependency:

In most of the real life scenarios, node velocity, acceleration and rate of change of direction directly depends on time. Hence, current velocity of a mobile node at a time depends on its previous velocity. This mobility characteristic is called temporal dependency. However, the RWP mobility model is unable to capture this behavior.

2.3.1 Gauss Markov Mobility Model:

The Gauss-Markov Mobility Model was first introduced by Liang and Haas [8]. This model captures the velocity correlation of a mobile node in time and represents random movement without sudden stops and sharp turns. At fixed intervals of time movement occurs by updating the speed and direction of each node.

After each iteration, the new parameter values are calculated depending on the current speed and direction and on a random variable. In this the velocity of a node at any time has been given as:

$$V_t^x = \alpha\, V_{t-1}^x + (1-\alpha)\, V^x + \sigma^x * \sqrt{(1-\alpha^2)} * W_{t-1}^x$$
$$V_t^y = \alpha\, V_{t-1}^y + (1-\alpha)\, V^y + \sigma^y * \sqrt{(1-\alpha^2)} * W_{t-1}^y$$

Where $V_t = [V_t^x, V_t^y]^t$ and $V_{t-1} = [V_{t-1}^x, V_{t-1}^y]^t$ are velocities of node at time t and (t-1) respectively, $\alpha = [\alpha^x, \alpha^y]^t$ is memory level, $V = [V^x, V^y]^t$ is representing mean, $\sigma = [\sigma^x, \sigma^y]^t$ is standard deviation and $W_{t-1} = [W_{t-1}^x, W_{t-1}^y]^t$ is uncorrelated Gaussian process with mean zero and variance.

Based on these equation Liang and Haas observe that the velocity of a node at time t depends on the velocity at time instant (t-1). Therefore, the Gauss-Markov model is a temporally dependent mobility model whereas the degree of dependency is determined by the memory level parameterα. This parameter also represents the randomness present in Gauss Markov mobility model. By adjusting this parameter Liang and Haas has state that this model can be applied to various scenarios.

1. If the Gauss-Markov Model is memory less, i.e., α = 0, then

$$V_t^x = V^x + \sigma^x * W_{t-1}^x$$
$$V_t^y = V^y + \sigma^y * W_{t-1}^y$$

Means velocity of a node at any time slot is determined by the drift velocity and Gaussian random variable.

2. If the Gauss-Markov Model has strong memory, i.e., α = 1, then

$$V_t^x = V_{t-1}^x$$
$$V_t^y = V_{t-1}^y$$

Means the velocity of mobile node at time slot't' is exactly same as its previous velocity.

3. If Gauss Markov mobility model has some memory i.e. 0< α <1, then the velocity at current time slot depend on both, its velocity at the time (*t-1*) and on Gaussian random variable *W*. As the value of parameter 'α' increases the velocity at current time will be more influenced by the velocity at previous time slot.

2.4 Mobility Model with Geographical Restrictions:

In most real life applications, node's movement is influenced by the many obstacles. In particular, the motions of vehicles are bounded to the freeways or local streets in the urban area, and on campus the pedestrians may be blocked by the buildings and other obstacles. Hence to capture all these scenarios two mobility models Free Way mobility model and Manhattan mobility model are used. In these mobility models movement is restricted by some geographical restrictions.

2.4.1 Free Way Mobility Model:

This model requires a map to guide the node movement. This model describes about freeway scenarios where roads are long straight with few number of turns. In this mobility model nodes are free to move along with its road and the velocity of a node is temporally dependent on the previous velocity.

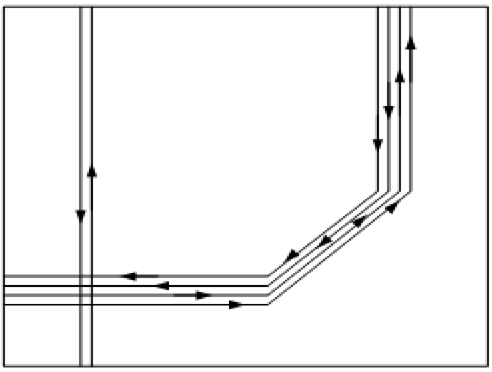

Fig-3: Map used in Freeway Mobility Model [6]

2.4.2 Manhattan Mobility Model:

This mobility model also requires a map for the node movement but the map is composed of a number of horizontal and vertical streets. Each street has two lanes for direction. The nodes are not allowed to change their lane in middle of it. In this model also nodes have temporal dependency as well as spatial dependency.

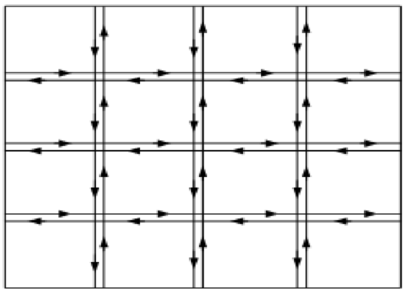

Fig-4: Map used in Manhattan mobility model [6]

III. RELETED WORK & ANALYSIS

Most of the work has been done in the direction to see the effects of mobility on the various routing protocols. Also some work has been done for the generation of realistic mobility trace, so that it can be used for the simulation purpose.

In [4], authors have studied about the performance of three widely used routing protocols, Destination Sequenced Distance Vector (DSDV), Ad-hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR) under different mobility models like RPGM, RWP, Gauss Markov and Manhattan mobility models. This work confirms that the choice of mobility model matters and the performance ranking of routing protocols depend on the node speed and the mobility involve in the network, since mobility cause for the link failure and each routing protocol reacts differently during link failure.

Alex Aravind and Hassan Tahir [5] have developed a software tool called RLMobiGen to design a realistic mobility model. Since, all the mobility models cannot be implemented particularly a mobility model involving realism a very challenging task to implement it. Using this software tool, desired mobility of the nodes in the system can be generated and analyzed, and then the trace can be exported to be used in the performance studies of proposed algorithms or systems.

In [6] author has observed that there is no clear winner among the routing protocols because different mobility models give different ranking of the routing protocols. For this analysis author had designed a framework, which mainly focuses on mobility characteristics such as average degree of spatial dependency, average degree of temporal dependency and average relative speed of nodes. Also, the framework define about the connectivity graph metrics having a set of parameters like average number of link changes, average link duration and average path availability. On these parameters any of the routing protocol can be compared under the given mobility model.

In [3] comparison of three routing protocols DSDV, AODV and DSR have done in three different real life scenarios in order to get significant results closer to the realistic scenarios. These scenarios are: conference room where the area has been divided into three zones, speaker zone, audience zone and entrance zone, event coverage are where people change their positions frequently for example a group of reporters covering a political event and disaster area where several rescue groups works together. In ad-hoc wireless network, network partitioning is another big issue [7]. It causes disruption of the ongoing routes, which affects the network performance severely. By exploiting the group mobility one can predict the future network partitioning and can minimize the disruption of routes.

In real life, there are many situations where there are several obstacles which come in between the way of mobile nodes. For example, Low-power radios used for indoor communication cannot propagate signals through walls, doors, and other obstacles in a building, without severe attenuation. Similar conditions may exist in an outdoor scenario, where objects in the terrain, such as buildings, cars, etc. may shadow radio transceivers. In order to get significant results in a simulation claiming to be realistic, obstacles to radio propagation should be modelled. Hence, authors have introduced three realistic scenarios, conference room, disaster area and event coverage to test the protocols.

IV. CONCLUSION

It is very important to use the best fit mobility model that can produce simulation results that are reliable both qualitatively and quantitatively. As mentioned in the previous section, researcher's need to carefully examine the models and the method with which the models are used in a simulation study to avoid interjecting sources of error. It is highly desirable to make simulation systems as realistic as possible within the constraints of complexity and cost. One approach is to use trace-driven simulation, which use real traces to trigger events in a simulation. Such an approach usually requires large amount of measured data. A cheaper but equally efficient way of achieving this is to build synthetic models after real data traces so that they generate synthetic/simulated traces similar to a real trace.

V. FUTURE WORK

To get the more accurate result of simulations it is important to propose a method to answer about the best fit mobility model for the given trace. This will certainly increase the accuracy of results obtained during simulation.

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